APPENDIX E
METALS SOURCE ANALYSES IN SUPPORT OF TMDL DEVELOPMENT FOR SANDBAR CREEK AND POORMAN CREEK DRAINAGES

Sandbar Creek Metals Source Analysis

In order to further quantify possible metals source areas, a metals loading analysis was performed for Sandbar Creek. In a metals loading analysis, the mass, or load (lb/day), of one or more metals is calculated using the measured streamflow rate (cubic feet per second) and corresponding metals concentrations determined from water quality samples collected at various points along a stream. By comparing the metal loads at various points, downstream changes in metals loads, or loading trends, can be determined. An increase in a metal load between two points indicates a source of metals loading exists between those two points. In this way a metals loading analysis can help identify specific loading sources within a drainage and aid in restoration planning.

Streamflow measurements were recorded and water quality samples collected at monitoring sites C03SNDBC01 and C03SNDBC02 on June 18, 2001, and at SCSW-1, SCSW-2 and SCSW-3 on October 7, 2002 (Figure 2-1 of Restoration Plan). Copper, iron and manganese loads were calculated for each sampling event since these metals were present at detectable concentrations at most sites. Sulfate loads were also calculated since sulfate can be an indicator of mine drainage resulting from oxidation of metal sulfide minerals.

The June 2001 metals and sulfate loads show consistent increases between upstream monitoring site C03SNDBC01 and downstream site C03SNDBC02 (Table E-1). This increase in loading, which is accompanied by a small increase in streamflow between the two sites (5.9 to 6.4 cfs), indicates the presence of one or more metals loading sources in this stream reach. The presence of copper in excess of the chronic aquatic criteria at upstream monitoring site SCSW-2 indicates one or more metals loading sources exist upstream of this point, such as the upstream mine dump and/or the apparent mine waste road fill (Figure 2-1).

The October 2002 metals concentrations trends are similar to the June trends although the October concentrations are lower. Copper, iron and sulfate loads consistently increase in a downstream direction, especially between downstream sites SCSW-1 and SCSW-2 resulting in water quality exceedences at SCSW-1. The smaller load increases observed between the two upstream sites indicate that the upstream sources (the upper mine dump and/or area of mine waste in road) continue to contribute metals to the creek during low flow, but at rates too low to cause water quality standards to be exceeded. The general lack of metals at upstream site SCSW-3 indicates an absence of upstream sources during low flow conditions.

Table E-1 Metals Loading Trends in Sandbar Creek for June 2001 and October 2002

	June 2001				October 2002					
	C03SNDBC01 (5.9 cfs)		C03SNDBC02 (6.4 cfs)		SCSW-3 (0.06 cfs)		SCSW-2 (0.10 cfs)		SCSW-1 (0.22 cfs)	
	Conc. µg/L	**Load lb/day**	Conc. µg/L	**Load lb/day**	Conc. µg/L	**Load lb/day**	Conc. µg/L	**Load lb/day**	Conc. µg/L	**Load lb/day**
Copper	5	**0.159**	11	**0.379**	1	**0.0003**	5	**0.0027**	22	**0.026**
Iron	70	**2.22**	260	**8.96**	<30	**<0.01**	40	**0.02**	1,020	**1.21**
Manganese	<5	**<0.151**	15	**0.517**	<10	**<0.003**	10	**<0.005**	120	**0.14**
Sulfate	7000	**222**	10	**344**	12000	**3.9**	15000	**8.1**	33000	**39**

Sites shown in upstream to downstream order.
Site locations shown on Figure 2-1

In summary, the metals loading analysis supports the previous findings that two mine waste dumps and a segment of road containing mine waste are likely sources of metals loading to Sandbar Creek. The downstream mine acts as the dominant source of metals loading under both high flow and low flow conditions, with low flow water quality exceedences restricted to the stream reach downstream of this mine. Based on the more extensive October 2002 sampling, no other upstream sources are believed to significantly affect water quality in Sandbar Creek, at least under low flow conditions.

Metals loading mechanisms may include leaching of dissolved metals from the mine waste to surface waters via infiltration of snowmelt/rainfall or contact with shallow groundwater, or transfer of particulate metals to the creek through erosion of the mine waste. The greater metals concentrations recorded under high flow as compared to low flow suggest erosion of particulate metals may be the dominant loading mechanism. More detailed water sampling immediately upstream and downstream of each source would be required to better quantify the relative load contributions from each source, and to assist with reclamation planning and prioritization.

Poorman Creek Metals Source Analysis

In order to identify general metals source areas, a metals loading analysis was performed for Poorman Creek. Table E-2 shows copper, iron and sulfate loading trends in Poorman Creek drainage as determined from the June 1996 water sampling data. The June 1996 sampling represents the most extensive high flow sampling event conducted in Poorman Creek drainage. Iron and copper were included in the loading analysis since these metals were consistently present at detectable concentrations in all water samples. Sulfate is included in the loading analysis as well since sulfate can be released from mine waste through the oxidation of metal-sulfide minerals, and therefore can be an indicator of mine drainage. Although extensive sampling was performed in Poorman Creek drainage in October 2002 (the only low flow data available from the majority of the drainage), a general lack of detectable metals concentrations in these samples precludes performance of a low flow loading analysis.

Table E-2 Metals and Sulfate Loading Trends in Poorman Creek Drainage for June 13, 1996

SITE	Description	Flow (cfs)	Copper (lb/day)	Iron (lb/day)	Sulfate (lb/day)
4128PO014	Swansea Gulch above Stemple Rd	0.79	0.043	0.21	26.8
011	Poorman Ck upstream of S. Fork	8.92	0.096	1.92	365
4128PO02	S. Fork Poorman Ck near mouth	17.66	0.095	3.81	571
4127PO01	Poorman Ck below McClellan Ck	56.97	0.614	6.14	2,240
4127PO02	Poorman Ck at NF boundary	59.05	0.318	22.3	2,290

Site listed in downstream order, locations shown on Figure 3-1.

Following is a summary of the June 1996 loading trends. Sampling locations are shown on Figure 3-1 of the Restoration Plan.

- June 1996 sampling sites include, in upstream to downstream order: Swansea Gulch near the confluence with Poorman Creek (site 4128PO014), Poorman Creek above the confluence with the South Fork (011), South Fork near the confluence with Poorman Creek (4128PO02), Poorman Creek below McClellan Creek (4127PO01), and Poorman Creek at the National Forest Boundary (4127PO02).

- Despite having the highest metals concentrations in the drainage (and the only exceedences of metals-related numeric water quality criteria), metals and sulfate loads in Swansea Gulch were low compared to other monitoring sites. This is due to the low flow rate (0.79 cfs), and thus lower dilution potential of Swansea Gulch, in comparison to Poorman Creek.

- Loads of copper, iron and sulfate were all greater at site 011 (Poorman Creek above South Fork) than those measured in Swansea Gulch. This indicates that loading sources in addition to Swansea Gulch exist upstream of site 011. Despite the higher loads, no water quality criteria were exceeded at 011 due to the higher flows (and greater dilution) in Poorman Creek.

- The South Fork (site 4128PO02) contained about twice the flow and iron load as compared to the mainstem above the confluence (site 011). The South Fork also contained a higher sulfate load while the copper load was almost identical between the South Fork and the mainstem.

- The Poorman Creek copper load increases by approximately 300% and the sulfate load approximately 400% between the confluence with the South Fork and site 4127PO01 (Poorman Creek downstream of McClellan Creek). The iron load through this reach was relatively unchanged. The copper load increase indicates the presence of one or more loading sources along this stream reach. The increase in sulfate load suggests sulfidic mine waste as the source.

- Between McClellan Creek and the National Forest Boundary (site 4127PO01 to 4127PO02), the copper load decreases, sulfate load and streamflow remain constant, and iron increases from 6.1 to 22.3 lbs/day (Table E-2). The decrease in copper load most likely reflects chemical precipitation of copper hydroxide (or other complexes) from the water column to the streambed. The large increase in iron load coupled with the stable sulfate load suggests an iron source other than sulfidic mine waste, possibly resuspension or dissolution of iron hydroxide precipitates previously deposited on the streambed.

Although the metals loading analysis indicates that multiple metals loading sources may exist throughout the drainage under high flow conditions, available water quality data indicate that only a small portion of the drainage (Swansea Gulch), is impaired due to elevated metals concentrations in the water column. As previously discussed however, elevated concentrations of some metals in Poorman Creek sediments, along with the available biological data, indicate that portions of Poorman Creek mainstem are impaired from metals.

Swansea Gulch contains a number of relatively large historic mines including the Swansea Mine/Tailings Complex and Silver Belle Mine (Figure 3-1 of Restoration Plan). This group of mines and support facilities, referred to here as the Swansea Gulch mines, represents the only currently identified source of metals-related water quality impairment in Poorman Creek drainage. Therefore, the first phase of TMDL development, load allocation, and restoration planning in Poorman Creek drainage focuses on Swansea Gulch, with allocations and restoration plans developed in subsequent phases once additional information on mainstem and tributary conditions becomes available.

Due to the importance of Swansea Gulch in development of a metals TMDL for Poorman Creek drainage, a brief summary of relevant available source assessment information from the drainage is presented below.

Swansea Gulch Water Quality

The former Montana Department of State Lands performed a preliminary evaluation of the Swansea Mine in 1993 as part of the state's ranking of Abandoned Hardrock Mine Priority Sites (MDSL, 1995). The evaluation identified an estimated 3,700 cubic yards of mine tailings and an estimated 15,000 yards of mine waste rock, and one discharging adit. Cadmium, lead, zinc, copper, manganese, antimony and mercury were identified as being present at elevated concentrations (three or more times background levels) in the tailings and/or waste rock.

Water samples were collected from the adit discharge, and from Swansea Gulch upstream and downstream of the mine. Analytical results from the adit discharge revealed no exceedences of human health or aquatic criteria, although the analytical detection limits utilized for cadmium and mercury were greater than the corresponding numeric criteria. Interestingly, sampling results from Swansea Gulch upstream and downstream of the mine revealed that metals concentrations were generally greatest in the upstream sample. The upstream sample exceeded the acute aquatic and chronic aquatic criteria for copper and lead, while the downstream sample exceeded these criteria for copper only. The MDSL preliminary evaluation concluded that there were no observed releases to Swansea Gulch and no exceedences of numeric water quality standards attributable to the Swansea tailings based on the information collected, although the evaluation did indicate a potential upstream source, which was not identified during the September 1993 investigation.

In addition to the 1993 water samples, one sample was collected in June 1996 (by MDEQ) and one in October 2002 (by Hydrometrics) near the mouth of Swansea Gulch. Metals concentrations in the 2001 sample exceeded applicable water quality standards for cadmium, copper and lead (0.5, 10, and 8 μg/L, respectively). Concentrations in the October 2002 sample were all below applicable standards. Water quality data from Poorman Creek drainage is included in Appendix C.